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(54) Title: WAVEGUIDE PAIR WITH CLADDING

(57) Abstract

A planar waveguide structure has, supported on a lower refractive index buffer layer (5), a pair of optical cores (1, 2) that, over at least a portion of their length, are closely spaced. These cores are covered with a layer (6) of cladding material comprising boron and phosphorus doped silica glass deposited by PECVD as a succession of individually annealed layers in order to minimise the incidence of voids in the deposit between the cores.

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WAVEGUIDE PAIR WITH CLADDING

Background to the Invention

The present invention relates to dielectric waveguide pairs made by plasma enhanced chemical vapour deposition (PECVD). This type of waveguide is frequently referred to as a planar waveguide, where the dielectric constant of the waveguide or core material differs slightly from that of a substrate material known as the buffer. The wavelengths transmitted by this type of waveguide will generally lie in the optical bands, e.g. 1-2μm for optical communication systems.

Summary of the Invention

The invention is particularly concerned with cases in which the relative refractive indices of the core and the buffer are such as to allow a significant amount of cross-coupling either from the cores, or between the cores, without undue losses. Such losses can arise from irregularities or discontinuities in the intervening medium.

Embodiments of the invention aim to provide cladding for the cores produced by PECVD which maintain good and low-loss optical coupling between the two waveguide cores.

According to the invention there is provided a waveguide device comprising in cross-section a buffer of dielectric material, elongated dielectric cores deposited on the buffer and of a different refractive index from that of the buffer, and a cladding arranged over the cores and over the buffer, at least in the neighbourhood of the cores, wherein the material of the cladding has a lower flowing temperature than that of the materials of the cores and buffer, and has a refractive index that approximates to that of the buffer. Preferably, the cladding material

consists essentially of a boron and phosphorus doped silica glass (BPSG).

When the buffer is pure silica, its refractive index is matched by the cladding and its flowing temperature satisfactorily exceeds that of the cladding.

A feature of preferred embodiments is that the cladding is in a layer constructed in stages. It is believed that, in combination with the choice of material for the cladding, namely BPSG, the use of a multi-deposit process minimises the creation of air voids or other physical imperfections that may cause discontinuities and accordingly reduces the undesirable lossy wave coupling between the cores which otherwise tends to occur.

The use of twin dielectric cores on a buffer of silica or other material, and enveloped in dielectric cladding, is known in planar waveguide techniques.

Brief Description of the Drawing

The invention will be further explained with reference to an embodiment by way of example, in conjunction with the accompanying drawing, which shows a transverse section across a planar waveguide illustrating schematically an undesirable fault which is largely eradicated by the use of the invention.

Detailed Description of a Preferred Embodiment

Referring to the drawing, the planar waveguide seen in cross-section is assumed to extend an appreciable distance into and out of the plane of the drawing, for transmitting the optical energy longitudinally and for coupling some energy across to the intervening medium. The coupling devices may be a Y-junction, a directional coupler or a radiative star and the like, where parallel lengths of waveguide are as close as less than one micron (1μm) to each other. The figure shows two waveguide cores 1, 2 which have been deposited on a substrate 4, suitably of silicon, with an intervening buffer layer 5. Buffer layer 5, which is

preferably of silica inhibits the optical fields arising during operation from interacting with substrate 4. The cores and the buffer, at least in surrounding regions, are covered with a layer of cladding 6 which may be 20μm or more thick, and which plays protective and optical roles.

If the heights of the waveguide cores shown schematically at 1, 2 are 5μm it is very difficult to apply a cladding 6 to the region 3 between the waveguides. The cladding 6 in this region 3 tends to have overhangs and voids, such as that shown schematically at 7, due to significantly less material being deposited.

Overhangs and voids cause abrupt changes in refractive index, which leads to undesirable energy losses and reflections, which tend moreover to be unpredictable.

In this embodiment a process for applying cladding to closely spaced cores has been developed which reduces the tendency of these undesirable defects to form in the region 3 between the cores. According to this embodiment firstly the buffer 5 is deposited on the substrate. The next stage is to deposit core material by PECVD, and then to selectively etch the deposited core material to leave a pattern of two cores 1, 2 with an intervening volume 3 in the form of a channel of rectangular cross-section. The cores are typically 5μm deep and about 6μm in width with a separation channel between the cores having a width typically in the range from 1 to 8 μm. It is believed that, with two such closely spaced cores, the amount of cladding 6 material that can be deposited as a final step by PECVD in the region 3 depends upon the range of angles from which material can reach the region. Hence the occurrence of the formation of overhangs and voids, such as that shown schematically at 7, which may be 3μm wide, may be minimised.

Such an undesirable void would prejudice the coupling action of the device, and this embodiment includes a special cladding process, as the final deposition step, incorporating boron phosphorus silica glass as the composition of the material of cladding 6. The cladding includes four stages of deposition and annealing, as follows.

Stage 1: Deposit 1.0µm of BPSG, then flow at 1000°C for 1 hour.
Stage 2: Deposit 3.2µm of BPSG, then flow at 1000°C for 1 hour.
Stage 3: Deposit 6.6µm of BPSG, then flow at 1000°C for 1 hour.
Stage 4: Deposit 6.6µm of BPSG, then flow at 1000°C for 1 hour.

The cladding composition is silica glass containing 2.4 weight % Phosphorus and 3.4 weight % Boron. The composition is suitable for the deposition, and also has a lower flowing temperature than the cores 1, 2 and has a refractive index close to that of the pure silica buffer 5. Optical performance has improved performance in comparison with previously produced cladding.

Claims:

1. A cladded waveguide pair produced by plasma enhanced chemical vapour deposition (PECVD) on a buffer layer (5) on a substrate (4), with a cladding layer (6) of boron and phosphorus doped (BPSG) produced by multiple stages on the waveguide pair and adjoining regions of the buffer wherein each stage consists of a deposition step and a subsequent annealing step by which the cladding is flowed.

2. A cladded waveguide pair according to claim 1 in which the BPSG cladding layer has a lower flowing temperature than the core material and a refractive index close to that of the buffer.

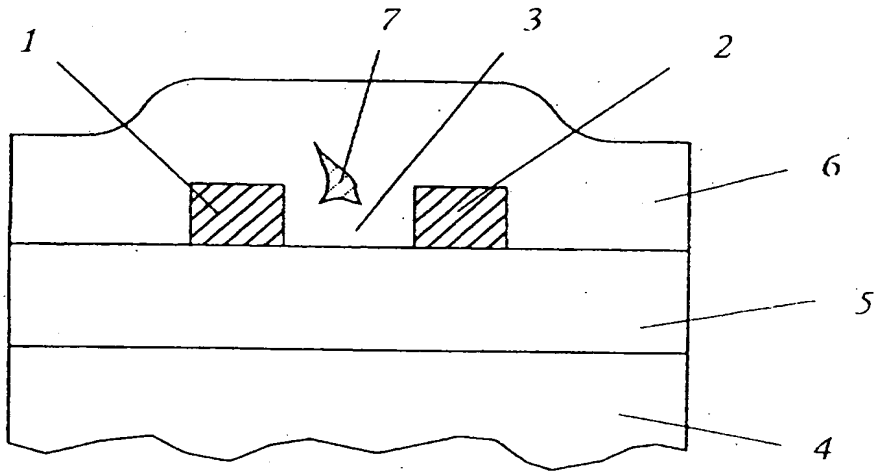
3. A cladded waveguide pair according to claim 2 in which the BPSG includes silica glass containing 2.4 weight % phosphorus and 3.4 weight % boron.

4. A cladded waveguide pair according to claim 1, 2 or 3 wherein the buffer is pure silica.

5. A method of producing a cladded waveguide pair by PECVD comprising depositing a buffer layer (5) on a substrate (4), depositing a pair of spaced waveguide cores (2) on the buffer layer, and producing a layer of cladding (6) on and near the core pair including the interval (3) between the pair, wherein the cladding is produced in multiple stages, each stage including a deposition step followed by step of annealing in which the deposited material is flowed.

6. A method according to claim 5 wherein the layer of cladding includes BPSG silica glass consisting of 2.4% phosphorus and 3.4% boron.

7. A method according to claim 5 or 6 wherein each annealing step includes flowing 1000°C for one hour.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INTERNATIONAL SEARCH REPORT

Inte .onal Application No
PCT/GB 97/00040

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G02B6/13 G02B6/132 G02B6/125

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G02B C23C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 018, no. 295 (P-1748), 6 June 1994 & JP 06 059147 A (HITACHI CABLE LTD), 4 March 1994, see abstract ---	1,3,5,6
A	PATENT ABSTRACTS OF JAPAN vol. 017, no. 553 (P-1625), 5 October 1993 & JP 05 157925 A (NIPPON TELEGR & TELEPH CORP), 25 June 1993, see abstract --- -/--	1,2,5

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	ELECTRONICS LETTERS, vol. 29, no. 12, 10 June 1993, pages 1123-1124, XP000374764 IMOTO K ET AL: "HIGH REFRACTIVE INDEX DIFFERENCE AND LOW LOSS OPTICAL WAVEGUIDE FABRICATED BY LOW TEMPERATURE PROCESSES" see the whole document ---	1,4,5
A	US 4 953 934 A (IMOTO KATSUYUKI ET AL) 4 September 1990 see column 2, line 38 - line 63 see column 3, line 17 - line 39 see figures 2,3B,4B ---	1,5
A	US 4 911 513 A (VALETTE SERGE) 27 March 1990 see column 7, line 41 - line 68 see column 8, line 1 - line 18 see figures 10-14 -----	1,4,5

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Inter. ..ional Application No
PCT/GB 97/00040

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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Article 37 of the Patent Law

Article 37 states to the effect that;

A patent application shall have one claim claiming one invention, but may have an additional claim(s) claiming any of the following inventions having a relationship as indicated below with the one invention ("specified invention"):

(i) inventions of which the industrial applicability and the problem to be solved are the same as those of the specified invention;

(ii) inventions of which the industrial applicability and the substantial part of the features indispensable for the constitution of the invention are the same as those of the specified invention;

(iii) where the specified invention relates to a product, inventions of process of manufacturing the product, inventions of process of using the product, inventions of process used for handling the product, inventions of machine, instruments, equipment or other things used for manufacturing the product, inventions of products solely utilizing the specific properties of the product, or inventions of things used for handling the product;

(iv) where the specified invention relates to a process, inventions of machines, instruments, equipment or other things used directly in the working of the specified invention; and

(v) inventions having a relationship as provided for in a cabinet order.

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(ii) inventions of which the industrial applicability and the substantial part of the features indispensable for the constitution of the invention are the same as those of the specified invention;

(iii) where the specified invention relates to a product, inventions of process of manufacturing the product, inventions of process of using the product, inventions of process used for handling the product, inventions of machine, instruments, equipment or other things used for manufacturing the product, inventions of products solely utilizing the specific properties of the product, or inventions of things used for handling the product;

(iv) where the specified invention relates to a process, inventions of machines, instruments, equipment or other things used directly in the working of the specified invention; and

(v) inventions having a relationship as provided for in a cabinet order.